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This is a U.S. NONPROVISIONAL Patent Application for:

Title: **METHODS FOR IMPROVING BUS PERFORMANCE AND
BANDWIDTH UTILIZATION OF A PARALLEL BUS LAN**

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IN THE UNITED STATES
PATENT AND TRADEMARK OFFICE
PATENT APPLICATION

5 METHODS FOR IMPROVING BUS PERFORMANCE AND BANDWIDTH
 UTILIZATION OF A PARALLEL BUS LAN

BACKGROUND OF THE INVENTION

10 1. Field of the Invention

 The invention relates to methods for improving
the performance and bandwidth utilization of a local area
network (LAN). More particularly the invention relates
to glare and collision avoidance bus arbitration
15 techniques used to maximize the performance and bandwidth
utilization of a parallel bus LAN.

2. Brief Description of the Prior Art

 Current LAN's are primarily of two types: token
20 ring and Ethernet(TM). Both token ring and Ethernet
require specific hardware to be installed into the
terminal stations (PC's, Printers, etc.) in order to
access the network. The networks are connected as
logical rings or a single bus and follow a serial data
25 protocol throughout the network. The presently preferred
and most popular network is the Ethernet network.

 Ethernet is basically a serial link protocol.
It can be implemented in twisted pair wiring, coaxial
30 cable, or glass fiber (FDDI). All cabling must be

terminated at each end with an Ethernet transceiver
adapter. It operates using broadcast technology, whereby
each station transmits in a serial manner and is received
simultaneously by all other stations on the immediate
5 network. The transceivers implement carrier-sense
multiple access with collision detection (CSMA/CD)
technology. Ethernet frames are between 46 and 1500
bytes. Physical connection of Ethernet stations can be
from Station to Station, or the network can be connected
10 via a central hub. The stations can detect when the
carrier is being used and back off to avoid collision.
When a collision is detected by a transceiver, it invokes
a back-off algorithm, which causes the transceiver to
wait a random period of time before attempting another
15 broadcast on the network.

Although it is virtually the industry standard,
Ethernet has several disadvantages:

20 Studies have shown that during periods of heavy
traffic, utilization of the Ethernet can fall to 40% or
less of the available bandwidth.

Ethernet requires compatibility of all stations in
25 both hardware and protocol in order for the stations to
access the network. For PC's this means an Ethernet
compatible NIC (Network Interface Card).

Ethernet requires a dedicated medium (coax, twisted pair, etc.) in order for a station to access the network.

Ethernet hubs are limited in the number of ports
5 that they can accept. Expansion means replacing the hub with a hub of larger capacity or adding another hub, either of which may result in unused capacity.

Bandwidth is limited to the discrete values
10 established by the industry (e.g. 10k, 100k, and 1,000k). To achieve higher bandwidth more and more exotic and expensive technology will be required.

SUMMARY OF THE INVENTION

15 It is therefore an object of the invention to provide a local area network.

20 It is also an object of the invention to provide a local area network which is efficient even under heavy usage.

25 It is another object of the invention to provide a local area network which is adaptable to different hardware interfaces.

It is yet another object of the invention to provide local area network which does not require a dedicated medium for each station coupled to the network.

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It is another object of the invention to provide a local area network which is readily expandable to accommodate more users.

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It is still another object of the invention to provide a local area network which has a broadly selectable bandwidth.

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In accord with these objects which will be discussed in detail below, the local area network according to the invention is based on a parallel bus having nx8 data lines, \pm power lines, and a clock line. The bandwidth of the LAN is the product of the number of data lines times the clock speed. Bandwidth is therefore scalable by increasing either the clock speed, the number of data lines, or both. Access to the bus is provided via ports which include transceivers, a clock receiver, and a configurable hardware interface.

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According to the presently preferred embodiment of a port, one transceiver is provided for each data line and two FIFO buffers are provided in each port, one buffer for transmitting and one for receiving. According

to the presently preferred embodiment, eight data lines are provided and each FIFO buffer is 2 kilobytes deep.

Access to the bus is provided in a repeating variable length frame, a portion of which is dedicated to bidding for access to the bus. Each port is assigned an address based on a data line and a clock cycle. Bidding takes place during the first p clock cycles of the frame, where p is the number of data ports divided by the number of data lines, rounded to the next highest integer. For example, for 20 ports and 8 data lines, $p=20/8=2.5$, rounded to 3. Following bidding, the bidders' addresses are placed in a queue in order of priority of ports.

Before data is transmitted, the message length is transmitted during clock cycle $p+1$ and the destination address is transmitted during clock cycle $p+2$. The destination port may refuse the transmission during clock cycle $p+3$. If the transmission is not refused, data is transmitted during clock cycles $p+4$ through $p+4+n/b$ where n is less than or equal to the size of the buffers in bytes and b is the byte width of the data bus. Buffer bytes are written during a final timeslot $p+4+n/b+1$ where the message length is not evenly divisible by the byte width of the data bus.

The network of the invention becomes more efficient as usage increases. Because the queuing system employed is offline, ports govern themselves in respect

to bus access and there is no unseemly crowding for control when a port has relinquished use of the bus. Bidding is done in a calm and dignified manner, with the port having the highest priority allowed to use the bus
5 whenever two or more ports bid for access.

External stations can be of any nature.

The interface ports that are plugged into the LAN will each be unique to the station to which it is linked.
10 This means there can be ports that accept 19.6 Kbaud serial links and ports that accept 100 Mbaud Ethernet links. Since a 10 Megahertz 16 bit bus has a bandwidth of 160 megabaud, such an implementation can easily accept 100 Mbaud Ethernet ports.

15 The ports of the parallel bus LAN can accept any medium. Any electronic data that can be converted into digital form can be passed over the LAN. It is only necessary to design an interface port to do the
20 conversion. This means, among other things, that networks can be developed that use ADSL technology to implement high speed data connectivity across the existing telephone infrastructure with no impact on the voice switching network.

25

The parallel bus LAN can be designed as a relatively inexpensive backbone capable of accepting a large number of ports. The flexibility of the design leads to almost limitless numbers of configurations

involving bus frequency, bus width, port types, etc.

Bandwidth is virtually unlimited. The parallel bus LAN can be expanded to any practical width and any practical frequency. For example, a bus that is 64 bits wide

5 running at a clock speed of 100 MHz, has a bandwidth of 6.4 Gigabaud. This is easily achievable with existing technology. The individual stations continue to operate at whatever baud rate their existing ports are capable of. But with the parallel bus LAN, the network bandwidth
10 can be so increased that delays due to heavy usage will virtually disappear.

BRIEF DESCRIPTION OF THE DRAWINGS

15 FIG. 1 is a high level schematic diagram of a parallel bus LAN according to the invention; and

FIG. 2 is a high level schematic diagram of a bus port according to the invention.

DETAILED DESCRIPTION

Turning now to Figure 1, a parallel bus LAN 10 according to the invention includes a data bus 12, a
5 clock bus 14, a power bus 16 and a plurality of users or
"ports" 18, 20, 22. According to the invention, the
data bus 12 has $n \times 8$ data lines and each port includes a
transceiver for each data line. According to the
presently preferred embodiment, each port includes two
10 FIFO buffers (preferably 2KB each), one for incoming data
and one for outgoing data, and a hardware interface.
According to a preferred aspect of the invention, each
port has a hardware interface which is adapted
specifically for a particular piece of hardware. For
15 example, the hardware interface may be a serial port
link, an Ethernet port link, a USB port link, a
FireWire(TM) port link, etc.

Referring now to Figure 2, an exemplary
20 embodiment of a port 100 according to the invention
includes a plurality of transceivers 102a-102h, one for
each bit of the data bus, an output FIFO 104, an input
FIFO 106, a processor with output queue 108 and a
hardware interface 110. As shown in Figure 2, the
25 processor is coupled to all of the other components so as
to control the flow of data to and from the bus. The
interface 110 supplies data to the output FIFO 104 and
receives data from the input FIFO 106. Both FIFOs are
coupled to the transceivers which are coupled to the bus.

According to the invention, data is placed on the bus in a repeating, variable length, frame having the format shown in Table 1.

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Clock cycle	Data Bus Content
1	Bit mapped bids
⋮	Bit mapped bids
P	Bit mapped bids
P+1	Message length
P+2	Destination Address
P+3	Port busy
P+4	Data
⋮	Data
P+4+n/b	Data
P+4+n/b+1	Data+Buffer bits

Table 1

Each port is assigned an address based on a data line and a clock cycle as described in more detail below with reference to Table 2. Bidding takes place during the first p clock cycles of the frame, where p is the number of data ports divided by the number of data lines, rounded to the next highest integer. For example, for 20 ports and 8 data lines, $p=20/8=2.5$, rounded to 3.

Following bidding, the bidders' addresses are placed in a queue in order of priority of ports. All ports monitor the bus. Each port maintains a copy of the queue and writes to the bus in turn based on the queue. The queue contains the addresses of the ports that have unsuccessfully bid for the bus and are waiting for an opportunity to send a message. Ports are allowed to take possession of the bus in the order in which they placed their bids. When glare occurs (two ports bid at the same

time), the lower number address(higher priority) port receives the earlier position in the queue.

Before data is transmitted, the message length
5 is transmitted during clock cycle p+1 and the destination address is transmitted during clock cycle p+2. The destination port may refuse the transmission during clock cycle p+3. The transmitting port turns off its transmitters during the BUSY timeslot (p+3) to permit the
10 destination port a chance to refuse the message.

An address value is the decimal value assigned to the destination port. Ports read this address during the p+2 clock cycle and accept data from the bus when the
15 address is their own. If a port's buffer space is not sufficient for the message length, it will place a 0 on all the bits of the bus at the time of the BUSY timeslot in order to refuse the incoming message. In this case, the transmitting station truncates the message, places an
20 EOM code on the bus and bids again. The port wishing to transmit continues to attempt to transmit (via bidding and transmission) until the receiving station is able to accept the message.

25 If the transmission is not refused, data is transmitted during clock cycles p+4 through p+4+n/b where n is less than or equal to the size of the buffers in bytes and b is the byte width of the data bus. Buffer

bytes are written during a final timeslot $p+4+n/b+1$ where the message length is not evenly divisible by the byte width of the data bus. If the queue is not empty at the end of a message, the bidding process is skipped and the
5 next port in the queue takes possession of the bus following the buffer byte(s).

Bidding is the process whereby a port expresses its intention of taking possession of the data bus for
10 the purpose of transmitting a message to one or more other ports. A port wishing to send a message, places a 0 voltage on the bus on ALL bit positions for one timeslot to signal the beginning of a frame. Then it places a 0 voltage on the line corresponding to its bit
15 position at the time of its byte position. If, for example an 8 bit bus LAN is designed for 64 ports, the first 8 bytes of a frame are dedicated to the bidding effort. Together, these bytes compose a bid chart. Each bit of a byte represents a particular port, determined by
20 the value of that port's pre-assigned port number (from 1 to 64) as shown in Table 2. The formula to determine a port's bit position is $(\text{port number} / 8) = \text{byte number}$ and the remainder = bit number. If the bus width is some multiple of eight, the formula doesn't change, although
25 the timeslot location of the bit may change.

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	Port 7	Port 6	Port 5	Port 4	Port 3	Port 2	Port 1	Port 0
Byte 1	Port 15	Port 14	Port 13	Port 12	Port 11	Port 10	Port 9	Port 8
Byte 2	Port 23	Port 22	Port 21	Port 20	Port 19	Port 18	Port 17	Port 16
Byte 3	Port 31	Port 30	Port 29	Port 28	Port 27	Port 26	Port 25	Port 24
Byte 4	Port 39	Port 38	Port 37	Port 36	Port 35	Port 34	Port 33	Port 32
Byte 5	Port 47	Port 46	Port 45	Port 44	Port 43	Port 42	Port 41	Port 40
Byte 6	Port 55	Port 54	Port 53	Port 52	Port 51	Port 50	Port 49	Port 48
Byte 7	Port 63	Port 62	Port 61	Port 60	Port 59	Port 58	Port 57	Port 56

Table 2

5 The parallel bus LAN according to the invention allows the implementation of a true "star" LAN configuration which interfaces between two or more serial communication links. It provides a medium for serial links of disparate hardware types running at disparate speeds to exchange digital information without loss of data integrity and without suffering significant delays.

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In conjunction with the logical architecture described above, the LAN provides a physical interconnecting hub of scaleable bandwidth and minimal overhead with the versatility to meet almost any networking situation.

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The parallel bus LAN of the invention permits use of existing wiring infrastructure in a high speed data network, especially for, but not limited to, the telephony network. It provides highly efficient use of the network bandwidth and an elegant solution to heavy traffic situations. There is no possibility of any particular port losing out in contention arbitration. The LAN has the versatility to be implemented in very inexpensive hardware in applications where current technology would be prohibitively expensive or in state of the art technology to give performance untouched by any existing LAN.

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There have been described and illustrated herein a parallel bus LAN and an arbitration protocol for use therewith. While particular embodiments of the invention have been described, it is not intended that the invention be limited thereto, as it is intended that the invention be as broad in scope as the art will allow and that the specification be read likewise. It will therefore be appreciated by those skilled in the art that yet other modifications could be made to the provided invention without deviating from its spirit and scope as so claimed.